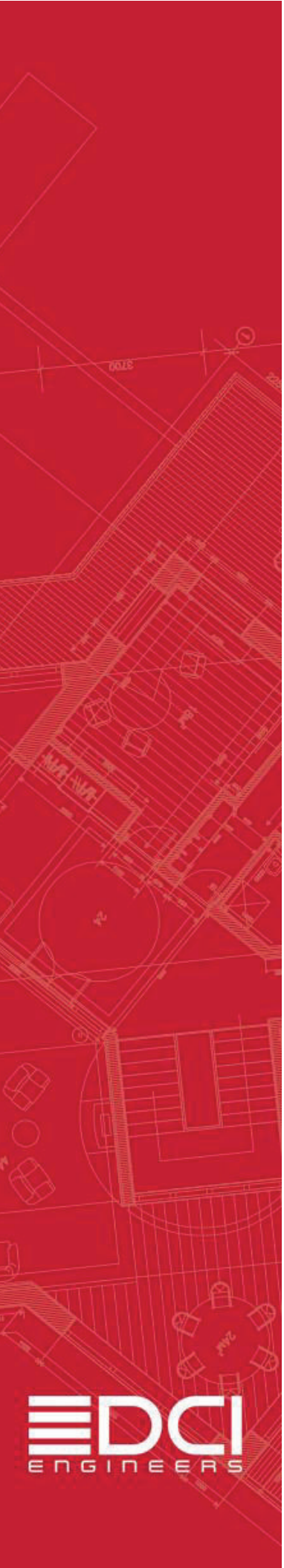

RediStair®
Lateral Model Study

Review of the impact of including the
RediStair® Assembly in a building lateral model
per Section 13.5.10 of ASCE 7-16

February 17, 2024

DCI ENGINEERS

RediStair® Basis of Design for Seismic Relative Displacements

Building Code Requirements

As outlined in ASCE 7-16, Section 13.5.10, egress stairs not part of the seismic force-resisting system of the structure to which they are attached shall be designed and detailed to accommodate prescribed seismic relative displacements. Under the Exception section in 13.5.10, if sliding or ductile connections are not provided to accommodate seismic relative displacements, the stiffness and strength of the stair shall be included in the building structural model and the stair shall be designed with an overstrength factor corresponding to the building seismic force resisting system but not less than 2.5.

RediStair® Structural System Overview

The standard RediStair® system consisting of precast concrete stair stringers and cast-in-place concrete main landings and mid-landings is rigidly connected to structural building slabs at each level and does not include sliding connections as outlined in ASCE 7-16, Section 13.5.10. Therefore, the RediStair® system must be designed using the provisions outlined in the Exception section noted above.

RediStair® Structural Design Process

The RediStair® structural system is designed independently for seismic relative displacements in accordance with ASCE 7-16. A three-dimensional finite element computer model of the stair system with appropriate stiffness properties for concrete is generated for each unique stair configuration. The model is then subjected to seismic relative displacements obtained from the building Engineer of Record in combination with seismic inertial forces. Results from these load combinations are used to obtain all necessary forces for proper design and detailing of reinforcing.

Recommendations on Inclusion of RediStair® System in Building Model

As noted above, because the RediStair® is rigidly connected to structural building slabs, ASCE 7-16 also requires that the stair be included in the structural building model. However, based on model studies performed to date, inclusion of the RediStair® system into the building model has very little effect on the primary building lateral system. The studies performed by DCI included adding the RediStair® system to a complete structural building model. The process of adding the stairs to the model took approximately 8-12 hours to complete depending on the size of the model. In most cases, the forces in primary building lateral elements and overall building seismic displacements are slightly lower when the stair system is included. DCI will design the RediStair® stair system to accommodate the seismic relative displacements provided by the building Engineer of Record.

Grant Buckingham, PE, SE
Vice President/Principal
818 Stewart Street, Suite 1000
Seattle, WA 98101
206.787.8922
gbuckingham@dci-engineers.com

As outlined in ASCE 7-16, Chapter 13, Section 13.5.10, DCI Engineers reviewed a sample building with RediStair® system stairs included in and excluded from the structural lateral model to see the impact to overall building stiffness.

The building used in the study is a 20-story special reinforced concrete shear wall building as shown in Figure 1. The stairs are modeled in their entirety, including mid-span landings between each main building floor.

The structural model consisted of two lateral force resisting core walls as shown in Figure 2. The wall stiffness was assigned at 50% to account for cracking. This meets the requirements of ASCE 7-16, Chapter 12 for the concrete lateral force resisting systems.

The out of plane stiffness of RediStair® system stairs were also assigned as 50% to account for minor cracking and loss of stiffness due to creep and shrinkage of concrete.

Both Equivalent Lateral Force as well as Response Spectrum studies were conducted to understand if any single method would have any impact with and without stairs modeled into the lateral model. The total time required to add the RediStair® system to the model and analyze the results was approximately 24-hours.

Based on the results from the model, as shown in Figure 3 through Figure 8, we can conclude that inclusion of the RediStair® Assembly in the lateral model reduces the overall building displacement by as much as 12% and reduces the wall shear stresses by as much as 3%. This is because the lateral stiffness of the stairs is significantly less than the lateral stiffness of the building shear walls.

Our analysis indicates that inclusion of RediStair® system stairs in a building model based on the provisions of ASCE 7-16 has very little impact on the relative displacement and stiffness between building floors and may reduce the internal force distribution between the shear walls and floor diaphragms.

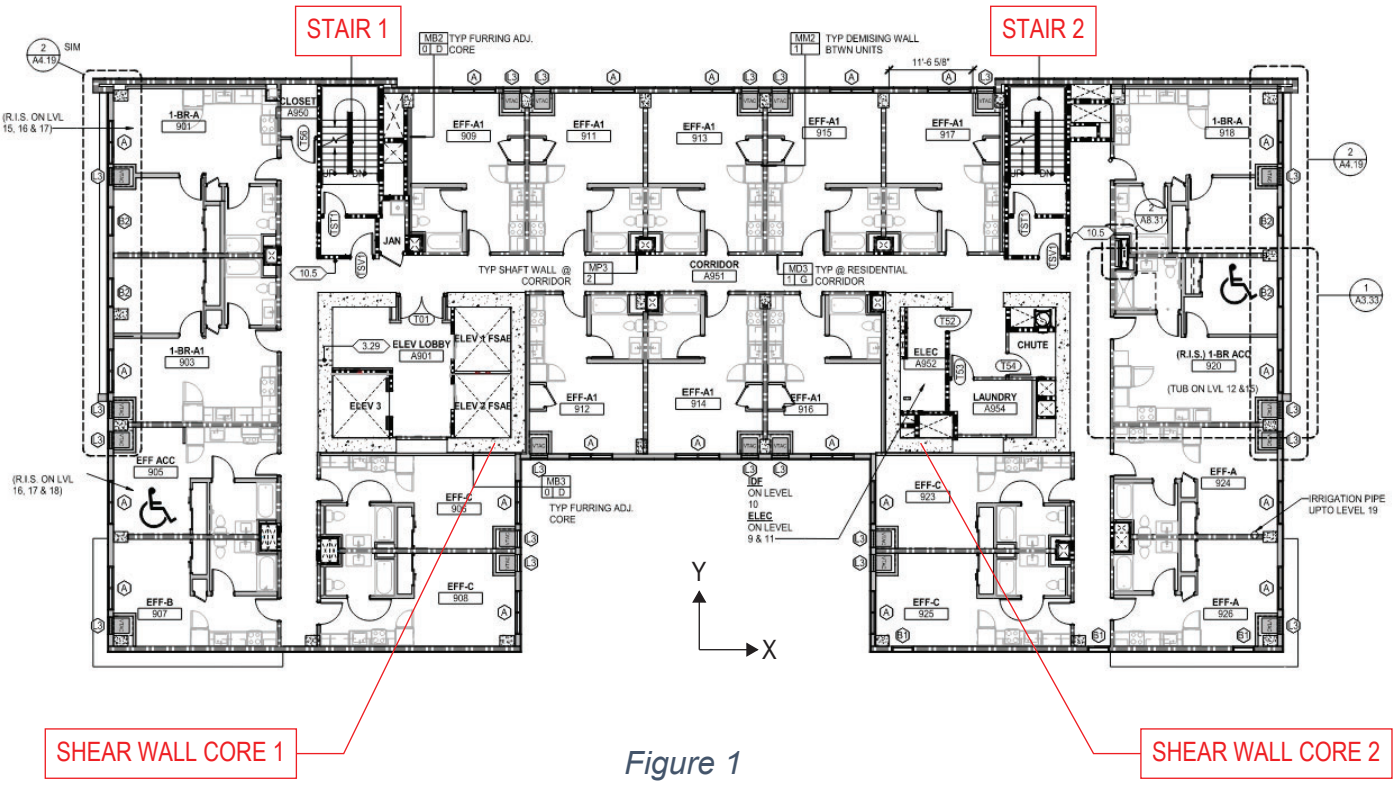
STAIR 1
STAIR 2
SHEAR WALL CORE 1
SHEAR WALL CORE 2
TYP FURRING ADJ. CORE
TYP DEMISING WALL BTWN UNITS
11'-6 5/8"
CLOSET A950
1-BR-A 901
EFF-A1 909
EFF-A1 911
EFF-A1 913
EFF-A1 915
EFF-A1 917
1-BR-A 918
JAN
TYP SHAFT WALL @ CORRIDOR
CORRIDOR A951
TYP @ RESIDENTIAL CORRIDOR
1-BR-A1 903
ELEV LOBBY A901
ELEV 1 FSAE
ELEV 2 FSAE
ELEV 3
EFF-A1 912
EFF-A1 914
EFF-A1 916
ELEC A952
CHUTE
LAUNDRY A954
(R.I.S.) 1-BR ACC 920
(TUB ON LVL 12 &15)
EFF ACC 905
(R.I.S. ON LVL 16, 17 & 18)
EFF-C 906
EFF-C 908
EFF-B 907
TYP FURRING ADJ. CORE
IDF ON LEVEL 10
ELEC ON LEVEL 9 & 11
EFF-C 923
EFF-C 925
EFF-A 924
EFF-A 926
IRRIGATION PIPE UPTO LEVEL 19
(R.I.S. ON LVL 15, 16 & 17)
SIM
Y
X

Figure 1

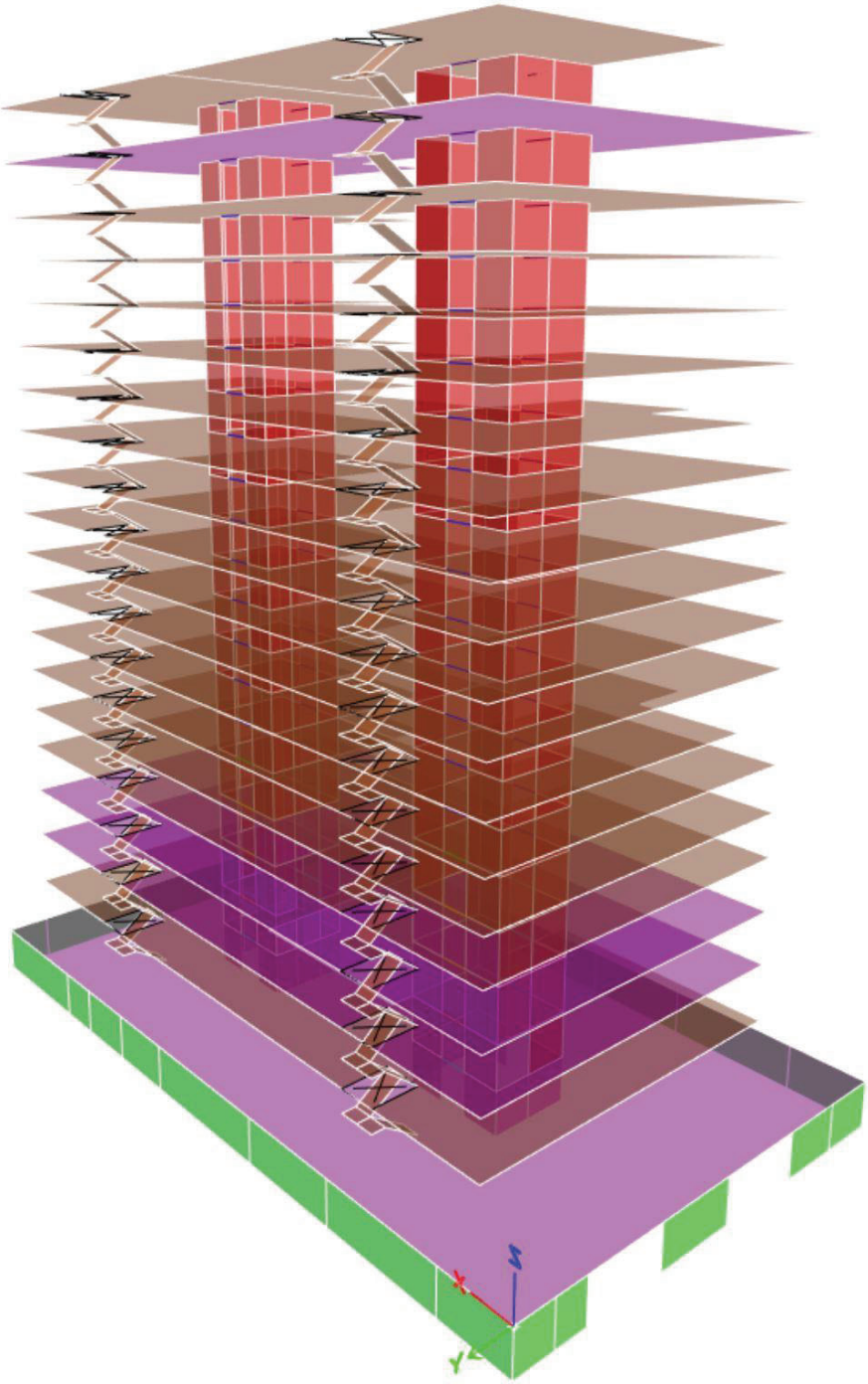

Figure 2

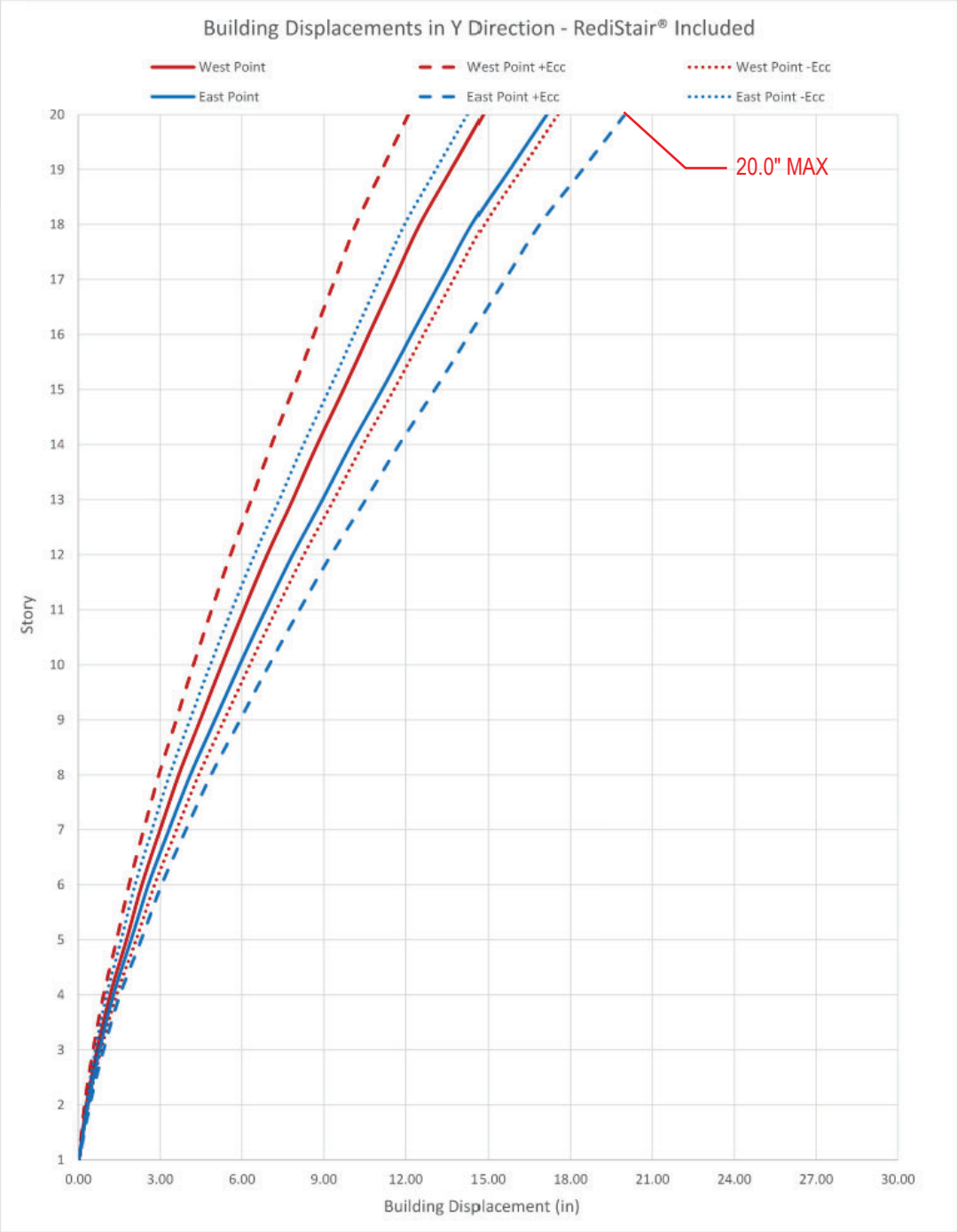
Building Displacements in Y Direction - RediStair® Included
West Point
West Point +Ecc
West Point -Ecc
East Point
East Point +Ecc
East Point -Ecc
20.0" MAX
Story
Building Displacement (in)
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
27.00
30.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure 3

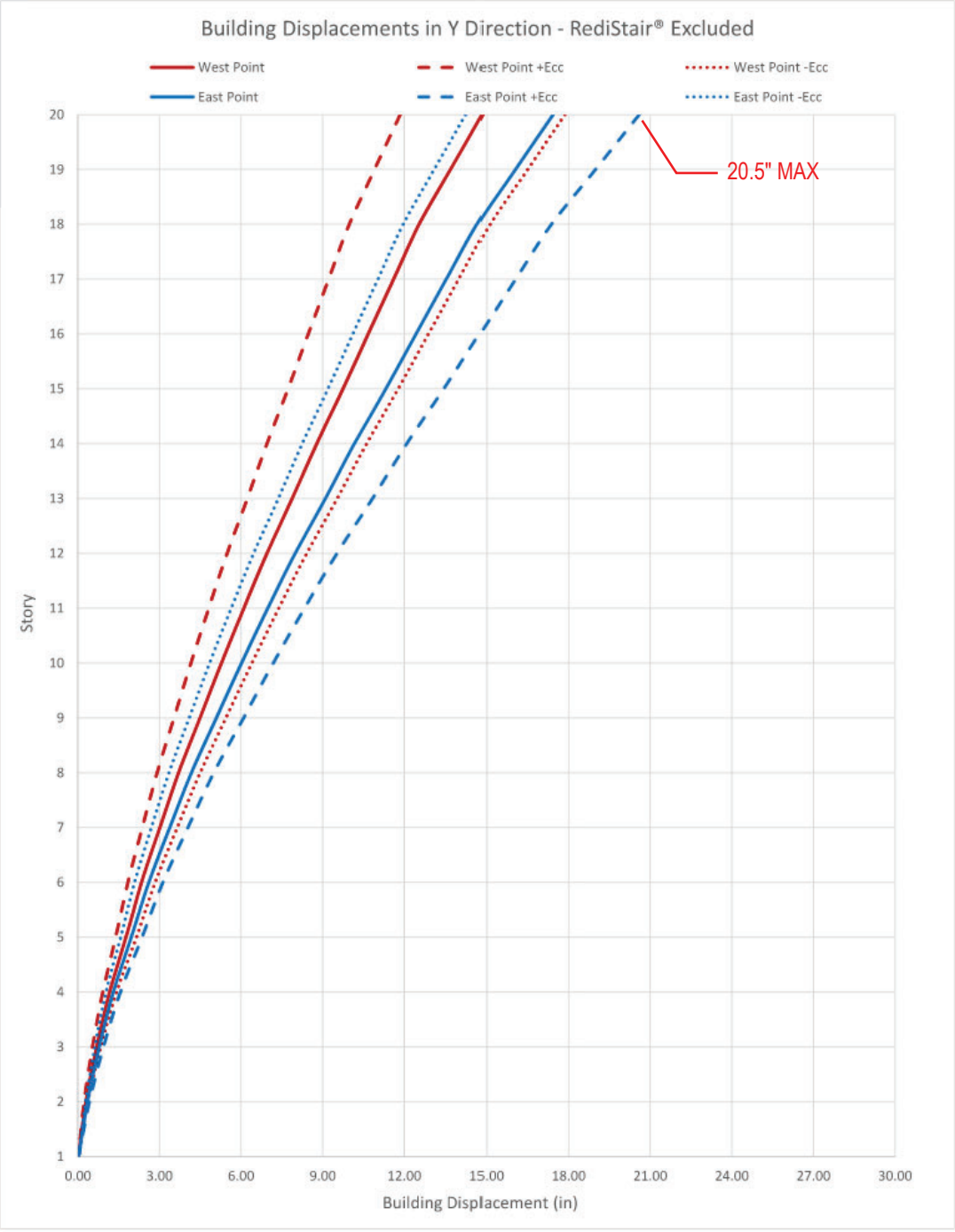
Building Displacements in Y Direction - RediStair® Excluded
West Point
West Point +Ecc
West Point -Ecc
East Point
East Point +Ecc
East Point -Ecc
20.5" MAX
Story
Building Displacement (in)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
27.00
30.00

Figure 4

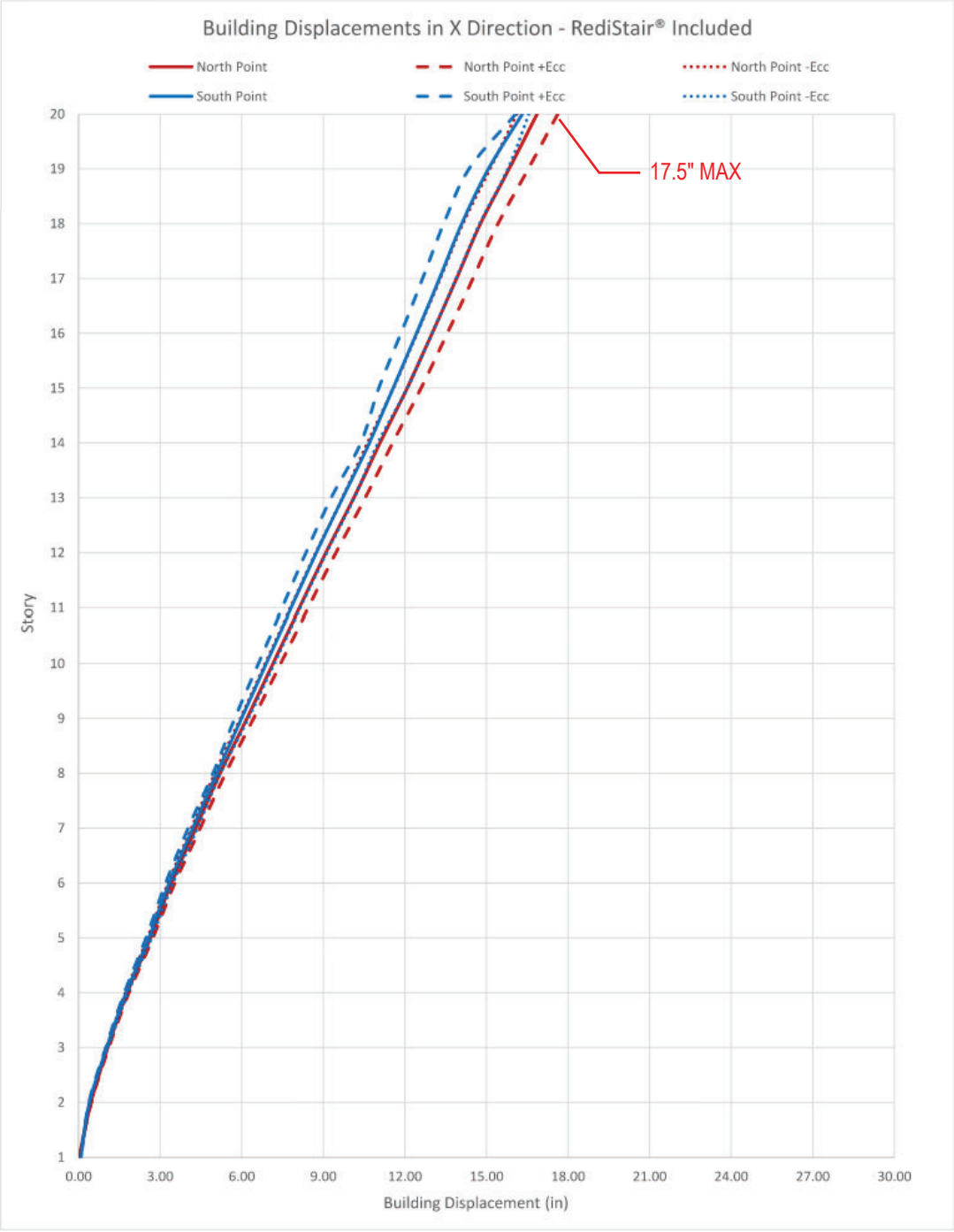
Building Displacements in X Direction - RediStair® Included
North Point
North Point +Ecc
North Point -Ecc
South Point
South Point +Ecc
South Point -Ecc
17.5" MAX
Story
Building Displacement (in)
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
27.00
30.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure 5

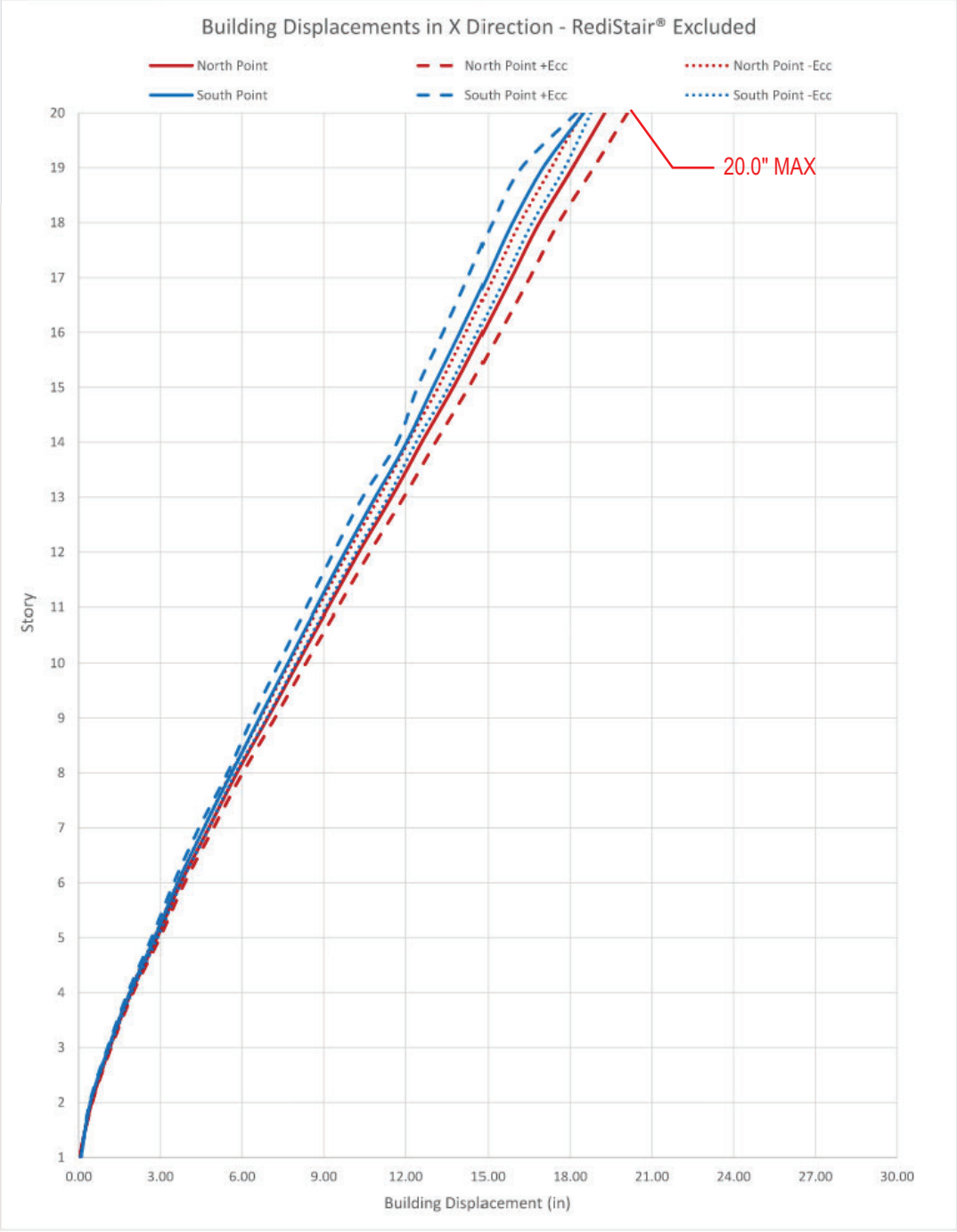
Building Displacements in X Direction - RediStair® Excluded
North Point
North Point +Ecc
North Point -Ecc
South Point
South Point +Ecc
South Point -Ecc
20.0" MAX
Story
Building Displacement (in)
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
27.00
30.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure 6

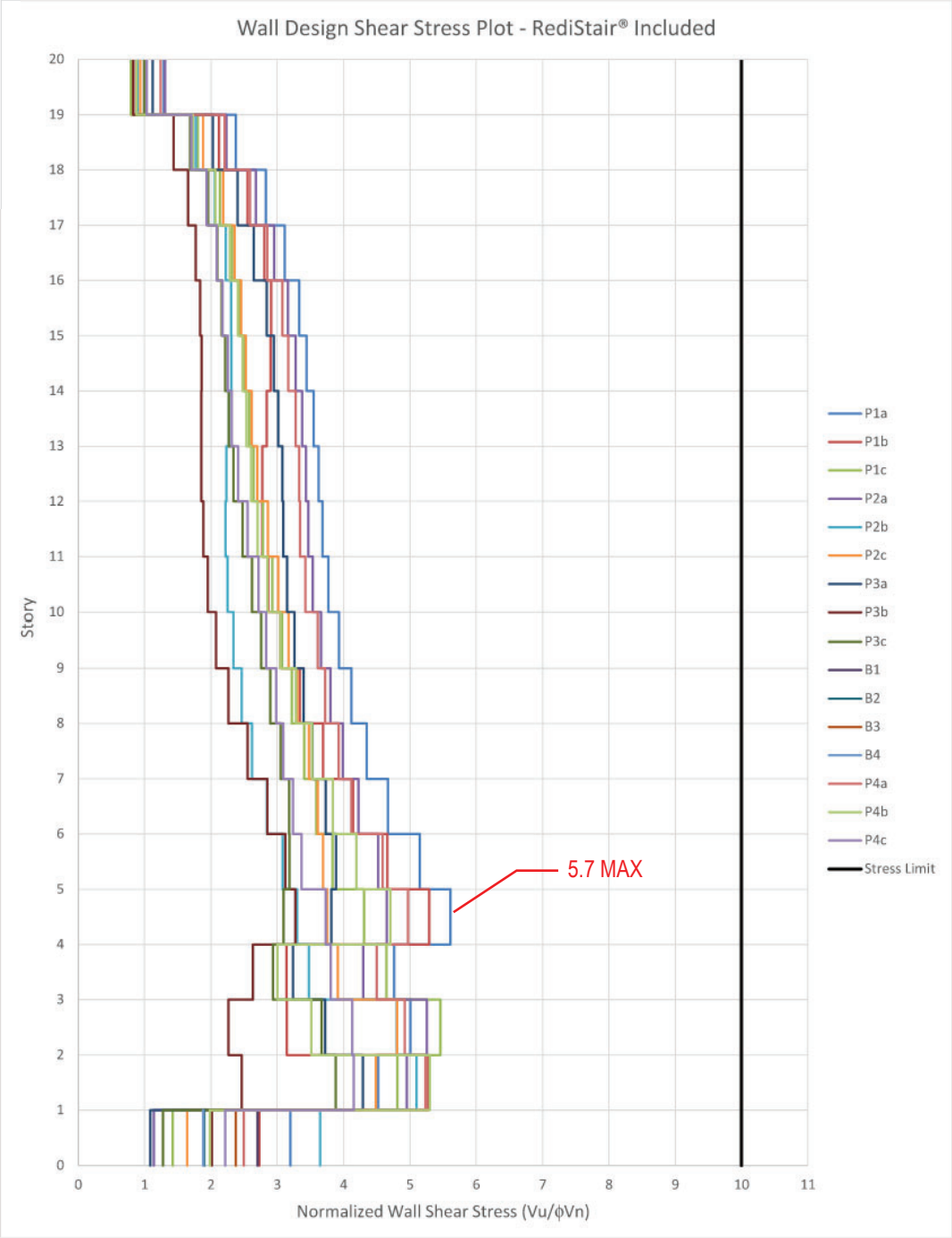
Wall Design Shear Stress Plot - RediStair® Included
Story
Normalized Wall Shear Stress (Vu/ϕVn)
5.7 MAX
P1a
P1b
P1c
P2a
P2b
P2c
P3a
P3b
P3c
B1
B2
B3
B4
P4a
P4b
P4c
Stress Limit

Figure 7

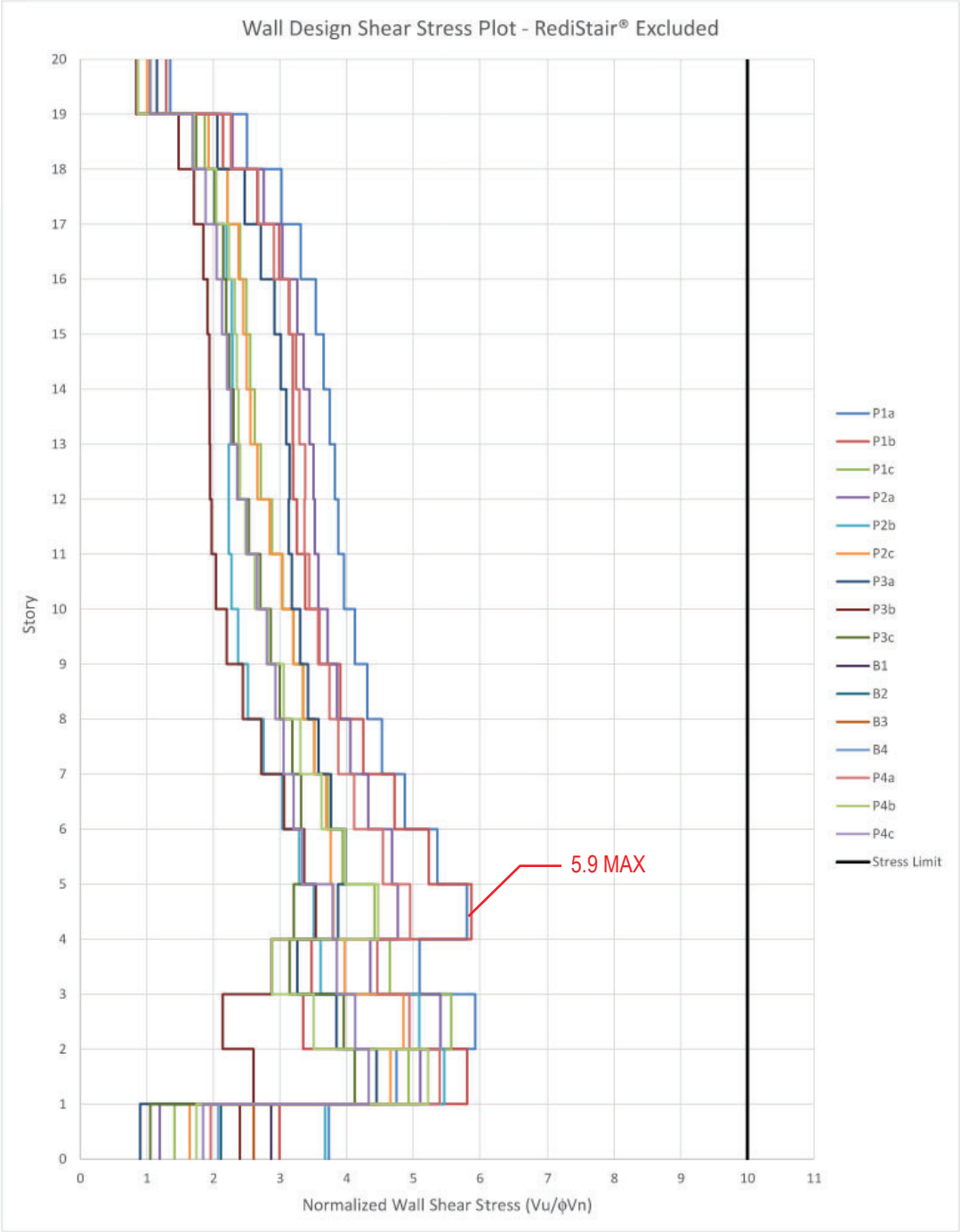
Wall Design Shear Stress Plot - RediStair® Excluded
Story
Normalized Wall Shear Stress (Vu/ϕVn)
5.9 MAX
P1a
P1b
P1c
P2a
P2b
P2c
P3a
P3b
P3c
B1
B2
B3
B4
P4a
P4b
P4c
Stress Limit

Figure 8